furnishes the chromatic element to the daughter nucleus. The cell walls rapidly meet in the centre, and their union is effected before the reconstruction of the daughter nuclei. The spindle mass contracts up to the middle of each of the four cells, and invests the young nucleus in the same manner as was the case with the original body.

Often during this part of the process there appeared to be two nuclei in each spore cell, but I regard this as probably due to an unequal contraction of the archoplasmic mass. In many of the daughter nuclei the two chromosomes could be detected for some little time, but they frequently become more numerous, and they finally lose their distinctness and are impossible to trace, though I leave, for the present at least, the question of their real permanence an open one.

[Since the above was written, I have seen a quadripolar spindle, also in *Aneura multifida*. It is not so well marked as in *A. pinguis*, and seems only to occur immediately before division. Its extremely short duration is indicated by the fact that, although I possess several hundred preparations, all fixed at nearly the same stage, in only two of them is there unequivocal evidence of the existence of such a spindle *before* the individualising of the chromosomes takes place.—November 21, 1893.]

V. "Sugar as a Food in the Production of Muscular Work." By Vaughan Harley, M.D., Teacher of Chemical Pathology, University College, London, Grocer Research Scholar. Communicated by George Harley, M.D., F.R.S. Received November 22, 1893.

It may be said to have been universally believed that proteids were the essential producers of muscular work until the experiments of Voit* and Pettenkofer† showed that, within certain limits, muscular work can be produced by carbohydrates. They did this by showing the relative amounts of nitrogen eliminated during muscular activity and repose. Subsequently, Chauveau and Kaufmann‡ showed, by comparing the quantity of sugar that disappeared from the blood traversing a muscle while contracting and at rest, that four times more sugar was used up during the period of muscular activity. Having failed to find any further recorded facts regarding sugar as a muscle food, I thought it desirable, in connexion with the investiga-

* Voit, 'Ueber d. Einfluss d. Muskelbewegung auf d. Stoffwechsel.' München, 1860.

† Pettenkofer and Voit, *ibid.*, vol. 2, p. 459, 1866.

‡ Chauveau and Kaufmann, 'Compt. Rendus,' vol. 103, 1886; vol. 104, 1887.

tion I have for some time been engaged upon, as regards the *rôle* played by sugar in the animal organism, to try and ascertain, by direct experiment, if sugar when taken as food is actually a supporter of muscular energy—a point of great value to be decided at the present moment, when sugar is so cheap that its use need no longer be restricted to that of a mere palatable condiment, but it might, perhaps, be profitably added to the daily diet of the working man as a muscular power-producing element.

With the object of, if possible, settling this point, I availed myself of the opportunity I had of making a series of experiments upon myself with Professor Mosso's ergograph, while working in the autumn of 1892 in the Physiological Laboratory at Turin.*

The amount of muscular energy developed by sugar was calculated by the quantity of work that could be done by the muscles of the middle finger of each hand, in a given time, before fatigue set in. And I think that the results obtained by experimenting with the fingers may not unreasonably be regarded as a reliable indication of the effects of sugar on the other muscles of the body.

Throughout the whole time of the experiments, except when it is specially mentioned to the contrary, not only was the mode of life, as regards the amount of sleep, &c., kept uniform and the same kind of food taken, but, as nearly as possible, in the same quantities, along with varying amounts of sugar taken.

Each separate experiment with the ergograph was repeated every two hours, a voluntary muscular contraction being made every two seconds. Being right-handed, a 4-kilo. weight was used for the right finger and a 3-kilo. one for the weaker left.

The total height to which the weight was raised, being multiplied by the weight, expressed in kilogrammetres the amount of work accomplished.

The amount of work done was calculated by two methods: firstly, the total amount of work accomplished up till fatigue set in; secondly, the amount of work accomplished by each thirty voluntary muscular contractions. The diurnal variations in the amount of work performed, as pointed out by Lombard,† and confirmed in my own experiments, rendered it necessary to compare the results at precisely the same hours on different days, in order to avoid error in drawing conclusions of the value of sugar, as the muscular working capacity varies at different times of the day.

The first step was to ascertain the value of sugar when taken alone

* I here beg to express my warmest thanks to Professor Mosso for kindly placing his apparatus at my disposal, and I may at the same time mention that his brother Professor Ugolino Mosso and Luigi Paoletti afterwards corroborated the results I obtained ('Report of the Roman Academy,' 15th October, 1893).

† Warren Lombard, 'Journal of Physiol.,' vol. 13, p. 1, 1892.

in the production of muscular work. During a twenty-four hours' fast—on one day water alone was drunk, on another day 500 grams of sugar was taken in an equal quantity of water.

Table showing the Increase in the Muscular Power of 30 Voluntary Contractions produced by 500 grams (17½ ounces) of Sugar.—200 grams (7 ounces) being taken at 8.30; 100 (3½ ounces) at 11 A.M., at 2 P.M., and 5 P.M.

Time of day.	Fasting.			Fasting + sugar.	
	Hand.	Weight raised, kilos.	Kilogram-metres by 30 contractions.	Kilogram-metres by 30 contractions.	Gain in work from sugar in kilogram-metres.
9.30 A.M.	Left	3	3·372	4·452	+1·080
11.30 „	„	„	3·273	4·812	+1·539
1.30 P.M.	„	„	3·513	4·524	+1·011
3.30 „	„	„	3·735	3·798	+0·063
5.30 „	„	„	3·186	3·873	+0·687
Total	„	„	17·079	21·459	+4·380 = 25·646 p. c.
11.20 A.M.	Right	4	3·112	3·552	+0·440
1.45 P.M.	„	„	2·892	3·200	+0·308
3.40 „	„	„	3·240	3·860	+0·620
5.45 „	„	„	2·300	4·704	+2·404
Total	..	..	11·544	15·316	+3·772 = 32·675 p. c.

The above table shows that sugar when taken alone increases the amount of muscular work done, as shown by thirty voluntary contractions. The left middle finger accomplished, during five periods, 21·459 kilos. of work, as against 17·079 kilos. on the fasting day, showing an increase in the muscle-working power, on sugar, of 25·646 per cent. The right hand, during the four periods when sugar was taken, performed 15·316 kilos. of work, as against 11·544 kilos. while fasting, thus showing the still higher gain in muscular power, on sugar, of 32·675 per cent.

The effect of sugar in retarding the approach of fatigue was next estimated.

Table showing the Power 500 grams (17½ ounces) of Sugar has of retarding Fatigue, as well as the total Increase in Muscular Power it produces.—200 grams (7 ounces) being taken at 8.30 A.M., and 100 grams (3½ ounces) at 11 A.M. and at 2 and 5 P.M.

Fasting.			Fasting + sugar.		
Time of day.	Time during weight lifted, seconds.	Total work, kilogram-metres.	Time during weight lifted, seconds.	Total work, kilogram-metres.	Gain in work, kilogram-metres.
Left middle finger raising a weight of 3 kilos.					
9.30 A.M.	78	3·408	94	5·949	+ 2·541
11.30 „	76	3·816	106	9·627	+ 5·811
1.30 P.M.	84	4·614	92	5·979	+ 1·365
3.30 „	66	4·245	118	6·381	+ 2·136
5.30 „	70	3·342	118	6·375	+ 3·033
Total...	374	19·425	528	34·311	+14·886 = 76 p. c.
Right middle finger raising a weight of 4 kilos.					
11.20 A.M.	88	4·028	100	4·080	+ 0·052
1.45 P.M.	78	3·380	114	4·376	+ 0·996
3.40 „	72	3·648	132	6·680	+ 3·032
5.45 „	62	2·420	138	6·564	+ 4·144
Total...	300	13·476	484	21·700	+ 8·224 = 61 p. c.

It is here seen that the 500 grams (17½ ounces) of sugar retarded the onset of fatigue by more than 150 seconds in both cases. The left middle finger being capable of working 528 seconds, as against 374 seconds; while the right worked 484 seconds, as against 300 seconds.

The total work performed by the left middle finger was 34·311 kilos. as against 19·425 kilos., giving a total gain of 76 per cent.; the right, 21·700 kilos. as against 13·476 kilos., yielding a total gain of 61 per cent. from the sugar.

When the result obtained from each successive working of the ergograph is compared, the total muscle-working power is apparently far more increased than that obtained from merely thirty contractions. This, in all probability, is due to the carbohydrates formed during fasting, from the proteids of the tissues, being sufficient for the performance of a small amount of work, though the supply is insufficient for prolonged work. When, however, sugar is taken, it supplies the

muscles with a sufficiency of working material, and the advantage, consequently, is most markedly seen in the total amount of work performed.

Having found that sugar when taken by itself is undoubtedly a muscular food, it was next necessary to ascertain its value when it is taken along with and in addition to an ordinary diet.

First, in order to see the effects of sugar added to a frugal meal, 200 grams (7 ounces) of sugar were taken at 9 A.M., after a breakfast, at 8 A.M., of a cup of coffee, with milk, and two rusks.

Table showing Gain in Muscular Work obtained by adding 200 grams (7 ounces) of Sugar to a Frugal Breakfast.

On coffee, milk, and rusks.			On coffee, milk, and rusks + sugar.		
Time of day.	Time during weight lifted, seconds.	Total work, kilogram-metres.	Time during weight lifted, seconds.	Total work, kilogram-metres.	Gain in work, kilogram-metres.
Left middle finger raising a weight of 3 kilos.					
9.30 A.M.	112	5·711	110	5·733	+0·022
11.30 „	122	6·477	124	7·206	+0·729
Total...	234	12·188	234	12·939	+0·751 = 6·162 p. c.
Right middle finger raising a weight of 4 kilos.					
9.40 A.M.	100	6·312	112	7·108	+0·796
11.40 „	122	7·556	180	12·176	+4·620
Total...	222	13·868	292	19·284	+5·416 = 39·06 p. c.

Here it is seen that 200 grams (7 ounces) of sugar increased the amount of work performed, both by the left and right hand. The increase in the quantity of work done being most marked in the case of the right finger, for it was 39·06 per cent., whereas the left was only 6·16 per cent. It is further seen that, although the taking of the sugar caused an immediate increase in the work done, the increase was far more marked two and a half hours later; that is to say, when its assimilation had taken place.

Having thus ascertained that sugar increases the power of doing muscular work when added to a small meal, I will now give an example of what it does when added to a full one; that is to say, a luncheon consisting of beefsteak with vegetables, an omelet, and

bread. along with a quarter bottle of red Italian table wine, and after it a small cup of black coffee.

In this case 250 grams (8½ ounces) of sugar were taken along with the meal at 12.30.

Table showing Gain in Muscular Work caused by the addition of 250 grams of Sugar to a Full Meal.

Time of day.	Luncheon.		Luncheon + sugar.		
	Time during weight lifted, seconds.	Total work, kilogram-metres.	Time during weight lifted, seconds.	Total work, kilogram-metres.	Gain in work, kilogram-metres.
Left middle finger lifting a weight of 3 kilos.					
2 P.M.	140	7·902	140	9·168	+1·266
4 „	130	7·533	150	8·511	+0·978
6 „	112	6·795	142	8·241	+1·446
Total ...	382	22·230	432	25·920	+3·690 =16·599 p. c.
Right middle finger lifting a weight of 4 kilos.					
2.15 P.M.	170	11·888	172	11·216	−0·672
4.15 „	163	11·188	220	13·648	+2·460
6.15 „	130	8·516	142	9·392	+0·876
Total ...	463	31·592	534	34·256	+2·664 = 8·433 p. c.

In this table it is seen that when 250 grams (8½ ounces) of sugar are added to a full meal the power of doing muscular work is increased.

In this instance it was the left hand that showed the greatest increase in working power, for it gave on the sugar day 16·599 per cent., while the right only yielded 8·433 per cent. more work. As usual, on both of the above days exactly the same quantities of food were taken, so that the only difference in them was the taking of 250 grams of sugar on the one and not on the other day. From this one is forced to conclude that sugar when added even to a copious meal has a most important power in increasing the human capabilities of doing muscular work.

I now give the result of the amount of work done on 250 grams of sugar in two periods of eight hours each, where in one case the sugar was taken in divided portions at three different times—100 grams (3½ ounces) at 8 A.M., and 100 grams again at 12 A.M., and 50 grams

(1¾ ounces) at 3.50 P.M.—the food partaken of, in all other respects, being on each day exactly the same.

Table showing total Gain in an eight-hour Day's Muscular Work produced by taking 250 grams (8¾ ounces) of Sugar in addition to an Ordinary Diet.

Ordinary diet.			Ordinary diet + sugar.		
Time of day.	Time during weight lifted, seconds.	Total work, kilogram-metres.	Time during weight lifted, seconds.	Total work, kilogram-metres.	Gain in work, kilogram-metres.
Left middle finger raising a weight of 3 kilos.					
9.30 A.M.	108	5·691	114	6·741	+ 1·050
11.30 „	102	6·219	106	6·651	+ 0·432
1.30 P.M.	112	7·131	102	7·742	+ 0·611
3.30 „	138	5·073	126	6·966	+ 1·893
5.30 „	84	4·830	108	7·221	+ 2·391
Total...	544	28·944	556	35·321	+ 6·377 = 22·032 p. c.
Right middle finger lifting a weight of 4 kilos.					
9.40 A.M.	112	7·108	172	11·664	+ 4·556
11.40 „	108	7·512	150	10·360	+ 2·848
1.40 P.M.	146	8·420	148	10·392	+ 1·972
3.40 „	126	7·236	148	8·880	+ 1·644
5.40 „	104	7·752	158	10·368	+ 2·616
Total...	596	38·028	776	51·664	+ 31·636 = 35·858 p. c.

It will be here noticed that the gain in work during the nine hours by taking sugar was in the case of the left finger 22·032 per cent., and the right finger 35·858 per cent. And that fatigue was retarded in the one case 12 seconds and in the other 180 seconds.

Thus it is seen that when 250 grams (8¾ ounces) of sugar is taken along with ordinary diet, it not only prolongs the time during which work can be done, but also increases the total amount of work performed in eight hours. It is further seen that the sugar taken at 3.50 P.M. had the effect of increasing the work done at 5.30 and 5.40 P.M., and that, instead of there being the usual diurnal fall in the amount of work done in the afternoon, there was actually an increase in the total amount of work accomplished.

Conclusion :—

1. Sugar when taken alone is a muscle food. 500 grams (17½ ounces) of sugar increased in my case the amount of muscular work done on a fasting day from 61 to 76 per cent.
2. The muscle energy-producing effect of sugar is so great that 200 grams (7 ounces) added to a small meal increased the total amount of work done from 6 to 30 per cent.
3. That when sugar was added to a large meal it increased the total amount of work done from 8 to 16 per cent.
4. That the work done during a period of eight hours can be increased from 22 to 36 per cent. by taking 250 grams (8¾ ounces) of sugar.
5. That when sugar is taken at 3.50 P.M. it not only obliterates the normal diurnal fall in the muscular power, which usually occurs at 5.30 P.M., but even causes an actual increase in the total amount of work done.

VI. "Note on some Changes in the Blood of the general Circulation consequent upon certain Inflammations of an acute local character." By C. S. SHERRINGTON, M.D., F.R.S. Received December 11, 1893.

(Abstract.)

This note describes, and attempts to interpret, in a preliminary manner certain anatomical alterations in the blood noted in experiments on the acute local inflammation of various tissues. The contents of the communication are as follows :—

I. (1) Description of the method employed for the induction of the local inflammation.

(2) Description of the methods followed in examining the composition of the blood.

II. Summary of the alterations observed. The chief of these alterations are (1) inspissation of the blood; (2) reduction of the number of hæmic leucocytes followed by increase of the number of them, followed in some cases by a final decrease of their number to below the original normal; (3) disturbance of the mutual ratios normal between the different kinds of hæmic leucocytes. The summary is illustrated by quotation of protocols from certain of the experiments—

α. When the site of inflammation is in the limb.

β. When the site of inflammation is primarily peritoneal.

γ. When the site of inflammation is primarily in a mucous surface.